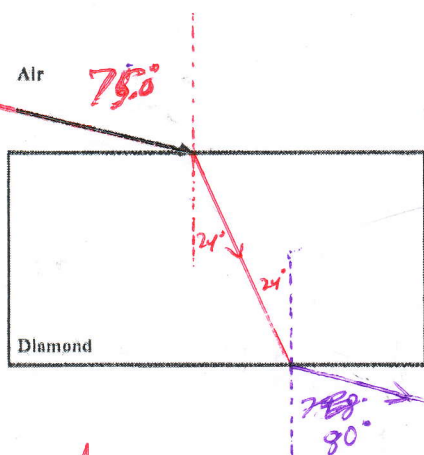


Name _____

Date _____

- ✓ 1. Light travels from crown glass into an unknown medium with an angle of incidence $\theta_i = 49.5^\circ$. What is the index of refraction of this medium if the angle of refraction was measured to be $\theta_R = 36.2^\circ$?
- ✓ 2. Light travels from ^{Ruby} Plexiglass into ^{Antifreeze} ruby. What is the angle of incidence if the angle of refraction is measured to be ~~16.8~~ ^{95.0}?
- ✓ 3. Light travels from water into diamond. What will be the angle of refraction in the diamond if the angle of incidence is 60.0° ?
4. A ray of light in air strikes diamond and another strikes a piece of fused quartz, in each case at an angle of incidence of 40.0° . What is the difference between the angles of refraction?
- ✓ 5. Light travels from zircon into fused quartz. What is the critical angle in the zircon?
- ✓ 6. In each of the following questions, the second medium is air. a) What is the critical angle if the index of refraction for a medium is 1.68? b) What is the index of refraction of a medium if the critical angle is 40.0° ?
- ✓ 7. What is the difference between the critical angle ^{for} light traveling from ruby-to-air and the critical angle for light traveling from water-to-air?
- ✓ 8. Light is traveling from water into crown glass. What is the largest possible ^{whole} angle of refraction?
- ✓ 9. What is the angle of refraction if light is traveling from diamond to water and the angle of incidence is 55.3° ?
10. What is the angle of incidence if light is traveling from water into zircon and the refracted angle is 62.5° ?
11. A cubic container contains air, water, glycerin, and diamond. There are no spaces between the boundaries of each and all boundaries are parallel. For light to travel through all of the substances, what is the maximum angle of incidence of the light ray in the diamond? (Hint draw a diagram to get started.)
- ✓ 12. In the image below, light is traveling from air into a rectangular piece of diamond. Draw the path that the light ray will take through the diamond, ~~and its path once it exits the diamond and determine the lateral displacement.~~ Label all angle measurements.



$$\sin \theta_c = \frac{n_2}{n_1} = \frac{1}{2.42}$$

$$\theta_c = 24.4^\circ$$

① Air-to-Diamond

$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$

$$\sin \theta_2 = \frac{n_1 \sin \theta_1}{n_2}$$

$$\sin \theta_2 = \frac{1 \sin 75^\circ}{2.42}$$

$$\theta_2 = 23.5^\circ$$

② Diamond-to-Air

$$\sin \theta_2 = \frac{n_1 \sin \theta_1}{n_2}$$

$$\sin \theta_2 = \frac{2.42 \sin 24^\circ}{1.00}$$

$$\theta_2 = 79.8^\circ$$

Total Internal Reflection Worksheet

5) $n_1 = 1.92$
 $n_2 = 1.46$
 $\theta_c = ?$

$$\sin \theta_c = \frac{n_2}{n_1}$$

$$\sin \theta_c = \frac{1.46}{1.92}$$

$$\sin \theta_c \approx 0.76042$$

$$\theta_c \approx 49.5^\circ$$

6) a) $n_1 = 1.68$
 $n_2 = 1.00$
 $\theta_c = ?$

$$\sin \theta_c = \frac{1}{1.68}$$

$$\theta_c \approx 36.5^\circ$$

b) $n_1 = ?$
 $n_2 = 1.00$
 $\theta_c = 40.0^\circ$

$$\sin \theta_c = \frac{n_2}{n_1}$$

$$n_1 = \frac{n_2}{\sin \theta_c}$$

$$n_1 = \frac{1}{\sin 40.0^\circ}$$

$$n_1 \approx 1.56$$

7) Ruby-To-Air

$$n_1 = 1.54$$

$$\sin \theta_c = \frac{n_2}{n_1}$$

$$n_2 = 1.00$$

$$\sin \theta_c = \frac{1.00}{1.54}$$

$$\theta_c = ?$$

$$\theta_c \approx 40.5^\circ$$

Water -to Air

$$n_1 = 1.33$$

$$\sin \theta_c = \frac{1.00}{1.33}$$

$$n_2 = 1.00$$

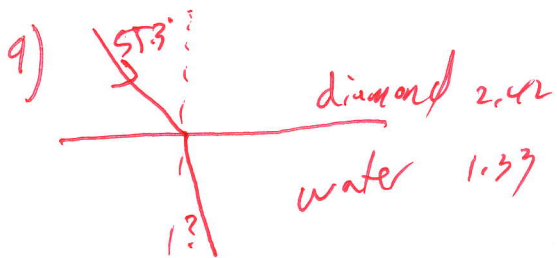
$$\theta_c = ?$$

$$\theta_c \approx 48.8^\circ$$

$$48.8^\circ - 40.5^\circ = 8.3^\circ$$

The difference is 8.3°

TIR 5, 6, 7



$$n_1 = 2.42$$

$$\theta_i = 55.3^\circ$$

$$n_2 = 1.33$$

$$\theta_c = ?$$

$$\sin \theta_c = \frac{n_2}{n_1}$$

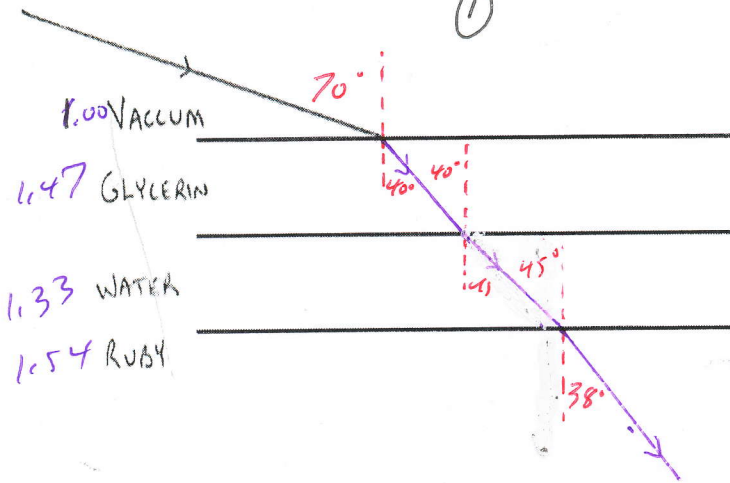
$$\sin \theta_c = \frac{1.33}{2.42}$$

$$\theta_c = 33.3^\circ$$

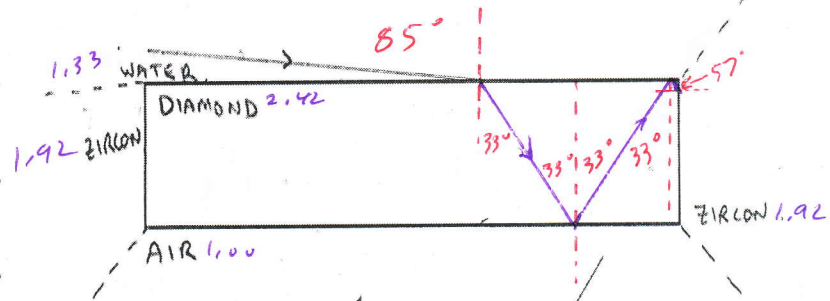
$55.3^\circ > 33.3^\circ \rightarrow$ Total internal reflection!
 \rightarrow No refraction

Trace the light rays through the substances

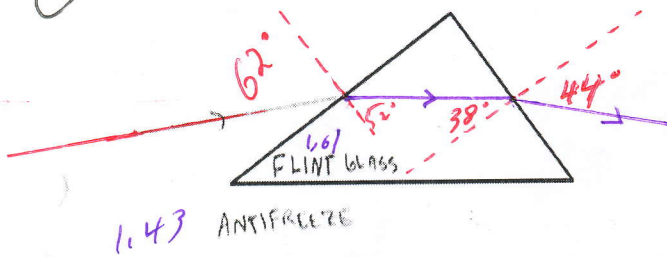
(1)



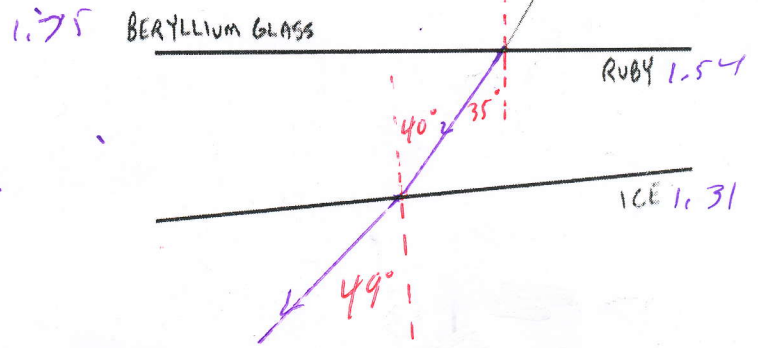
(2)



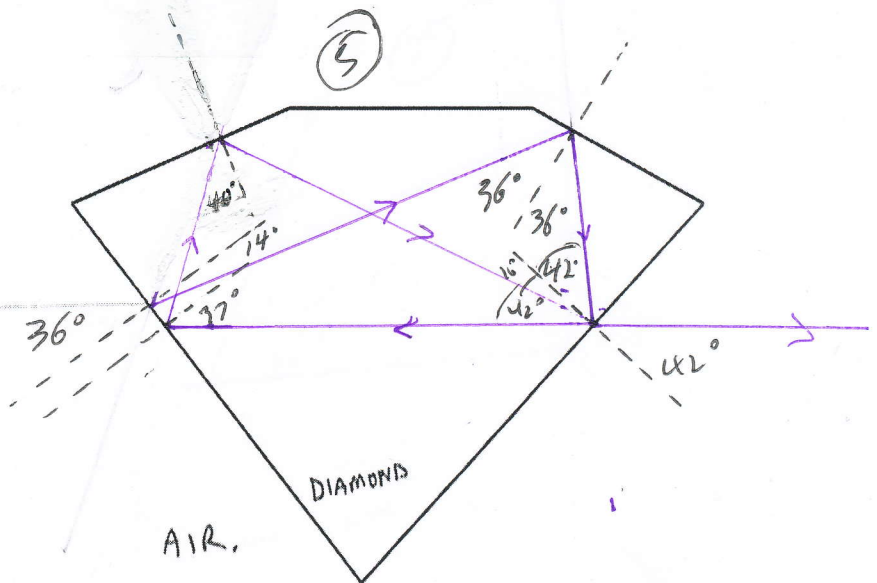
(3)



(4)



(5)



$$\sin \theta_2 = \frac{n_1 \sin \theta_1}{n_2}$$

Total Internal Reflection Tracing

① Vacuum - Glycerin

$$\sin \theta_2 = \frac{1.00 \sin 70^\circ}{1.47}$$

$$\theta_2 \approx 39.7^\circ \approx 40^\circ$$

Glycerin - Water

$$\sin \theta_2 = \frac{1.47 \sin 40^\circ}{1.33}$$

$$\theta_2 \approx 45.3^\circ \approx 45^\circ$$

Water - Ruby

$$\sin \theta_2 = \frac{1.33 \sin 45.0^\circ}{1.54}$$

$$\theta_2 \approx 37.6^\circ \approx 38^\circ$$

② Water - Diamond

$$\sin \theta_2 = \frac{1.33 \sin 85^\circ}{2.42}$$

$$\theta_2 \approx 33^\circ$$

Diamond - Air θ_c

$$\sin \theta_c = \frac{1}{2.42}$$

$$\theta_c \approx 24.4^\circ$$

\therefore Reflect

Diamond - water θ_c

$$\sin \theta_c = \frac{n_2}{n_1}$$

$$\sin \theta_c = \frac{1.33}{2.42}$$

$$\theta_c \approx 33.3^\circ$$

\therefore Reflect!

Diamond - Zircon θ_c

$$\sin \theta_c = \frac{1.92}{2.42}$$

$$\theta_c \approx 52.5^\circ$$

\therefore Bounce

Can stop here, as too tough to draw on our diagram.

③ Anti Freeze - Flint Glass

$$\sin \theta_2 = \frac{1.43 \sin 62^\circ}{1.61}$$

$$\theta_2 \approx 51.6^\circ \approx 52^\circ$$

Flint Glass - Anti freeze θ_c

$$\sin \theta_c = \frac{1.43}{1.61}$$

$$\theta_c \approx 62.6^\circ$$

Flint - Anti freeze

$$\sin \theta_2 = \frac{1.61 \sin 38^\circ}{1.43}$$

$$\theta_2 \approx 43.9^\circ \approx 44^\circ$$

(4) Beryllium Glass \rightarrow Ruby θ_c

$$\sin \theta_c = \frac{1.54}{1.75}$$

$$\theta_c = 61.6^\circ$$

Beryllium Glass \rightarrow Ruby

$$\sin \theta_2 = \frac{1.75 \sin 30^\circ}{1.54}$$

$$\theta_2 \approx 34.6^\circ \approx 35^\circ$$

Ruby \rightarrow Ice θ_c

$$\sin \theta_c = \frac{1.31}{1.54}$$

$$\theta_c \approx 58.3^\circ$$

Ruby \rightarrow Ice

$$\sin \theta_2 = \frac{1.54 \sin 40^\circ}{1.31}$$

$$\theta_2 \approx 49.1^\circ \approx 49^\circ$$

(5) Air \rightarrow Diamond

$$\sin \theta_2 = \frac{1.00 \sin 36^\circ}{2.42}$$

$$\theta_2 \approx 14.0^\circ \approx 14^\circ$$

Diamond to Air θ_c

$$\sin \theta_c = \frac{1.00}{2.42}$$

$$\theta_c \approx 24.4^\circ$$

Diamond to air

Bounce 4 times

$$\sin \theta_2 = \frac{2.42 \sin 16.0^\circ}{1}$$

~~$$\theta_2 \approx 55.9^\circ \approx 56^\circ$$~~

$$\theta_2 \approx 41.8^\circ \approx 42^\circ$$